Description

Computer tomography unit with a data acquisition system

The invention relates to a computer tomography unit (CT unit) having a radiation receiver which has a number of detector elements, having a data acquisition system for reading the electrical signals which are produced by the detector elements and for processing them to form raw data, and having an image computer which is arranged downstream from the data acquisition system and to which the raw data can be supplied via a data transmission path.

US 6,264,365 B1 describes the monitoring of CT data, which is carried out in the background, with respect to the existence and localization of a defective radiation receiver.

The invention is based on the object of specifying a computer tomography unit in which the influence of changes such as aging, wear, dirt or other external disturbance influences on operation can be further reduced.

With regard to the computer tomography unit mentioned initially, this object is achieved according to the invention by an evaluation device for automated assessment of the quality of the data acquisition system and/or of the data transmission path.

The evaluation device is optionally also designed for automatic assessment of the quality of the radiation detector.

For the purposes of the invention, the expression raw data means any initial data from the DMS, irrespective

of whether it has been produced with or without X-ray radiation arriving at the radiation receiver.

Advantageous refinements and developments of the computer tomography unit according to the invention are specified in the dependent claims.

The invention is based, inter alia, on the discovery that all of the components of a data measurement system (DMS) for a CT unit, which includes the radiation receiver, the data acquisition system (DAS) and the data transmission path, are subject to undesirable changes which have a negative influence on the image quality. Such changes may result from aging, wear or dirt on the components themselves, or else from external disturbance influences - which possibly occur only over the course of time.

The computer tomography unit according to the invention, that is to say in which an evaluation device is integrated, has the advantage that, after a start event (which is produced, for example, by a person or by the computer tomography unit), the evaluation device operates automatically and without any further inputs (or at least without any further complex inputs) and thus allows a quality assessment to be carried out without a major time penalty. It is thus possible for a technician in the manufacturing phase, on the test panel or during a service visit to quickly make a statement on the current quality of the operation of the DAS or about the data transmission path, and to do this without having to connect an external test set for this purpose and having to link this by data connection to the CT unit. Once a statement about poor quality or a negative test result is available, the technician can if necessary carry out component replacements, readjustment of components and/or repair of components in the CT unit.

A further advantage is that, since there are no interactive actions, the probability of errors in

carrying out the quality test is reduced, and the reproducibility of the test results is increased.

According to one preferred refinement, the following steps can be carried out by the evaluation device:

a) initiation of one or more measurements for production of raw data,
b) using the raw data, calculation of at least one value of at least one parameter which allows a quality statement,
c) driving of a display device (20) in order to display an evaluation result in which the calculated value is included.

The evaluation device preferably automatically initiates a change to the drive or setting of components in the CT appliance, in particular the X-ray beam source, the radiation receiver and/or the data acquisition system, while the measurement or measurements is or are being carried out, or between two measurements.

The advantages described above are obtained in particular if a number of parameters which indicate quality are displayed, in particular simultaneously, on the display device.

Since one or more predetermined parameters, that is to say parameters which are implemented in the evaluation device, are calculated using predetermined algorithms, that is to say a previously defined configuration process is carried out by the evaluation device or by its algorithms, and because the calculations are very largely carried out without any interaction with the user, the probability of errors in carrying out the quality test, and the reproducibility of the test results, are further improved, in terms of the latter also with respect to comparability of the test results

which are obtained with different computer tomography units in one and the same series, with the computer tomography units for this purpose all being equipped, for example, with the same evaluation device.

By way of example, the evaluation device first of all triggers the acquisition of raw data by measurements with or without X-ray radiation. The evaluation device can then determine the value of the parameter statistically from the measured raw data. Finally, the values of the parameter or parameters can be displayed.

It is advantageous for rapid acquisition of the quality state for the evaluation result to be displayed graphically on the display device, with the graphic including, in particular, a number of parameters relating to a graphical pattern, such as a bar chart, a column chart and/or a pie chart. A person carrying out the test can then see at a glance, and without having to record numerical values, whether or not the quality is "in the green band".

According to one development or alternative method of operation, tests which differ from one another can be carried out using configurations which differ from one another by means of different start events for the computer tomography unit according to the invention and, in particular, can also result in test patterns which differ from one another being displayed.

The alternatives, which comprise the determination of a number of parameters, can be illustrated as follows: let us assume that the linearity of a detector element and a quality value for the data transmission path have been predetermined as parameters. It is then possible to use a single start event to determine both the linearity parameter and the quality value, that is to say to obtain a comprehensive test result for a number of components in one procedure. Alternatively, start events which differ from one another can be used to carry out a test specifically on the detector element (linearity) or specifically on the data transmission path (quality value).

Further advantageous refinements and developments of the computer tomography unit according to the invention are included in the dependent claims.

One exemplary embodiment of a computer tomography unit according to the invention will be explained in more detail in the following text with reference to Figures 1 to 3, in which:

Figure 1 shows a computer tomography unit according to the invention, in the form of a schematic overall view,

Figure 2 shows a data acquisition system for the computer tomography unit shown in Figure 1,

Figure 3 shows a flowchart relating to the checking of the signal linearity of the detector channels,

Figure 4 shows a flowchart relating to the checking of the spectral linearity of the detector channels,

Figure 5 shows a schematic illustration of the checking of a data transmission path.

Figure 1 shows, schematically, a computer tomography unit according to the invention with an X-ray beam source 1 which emits a pyramid-shaped X-ray beam 2, whose edge beams are illustrated by dashed-dotted lines in Figure 1, which passes through an object being examined, for example a patient 3, and arrives at a radiation detector 4 which is equipped with a so-called UFC ceramic as a scintillator. The radiation detector 4 comprises 4 or 16 detector rows 5a to 5d, which are arranged alongside one another and have a number (for

example 672) of detector elements 6a to 6x arranged alongside one another.

The X-ray beam source 1 and the radiation detector 4 are arranged opposite one another on an annular scanning unit or gantry 7. The gantry 7 is mounted on

a holding apparatus, which is not illustrated in Figure 1, such that it can rotate with respect to a system axis 8 which runs through the center point of the annular gantry 7 (see the arrow a).

The patient 3 lies on a table 9 which is transparent for X-rays and which is mounted such that it can be moved along the system axis 8 by means of a mounting apparatus, which is likewise not illustrated in Figure 1 (see the arrow b).

The X-ray source 1 and the radiation detector 4 thus form a measurement system which can be rotated relative to the system axis 8 and can be moved along the system axis 8 relative to the patient 3, so that the patient 3 can have radiation passed through him from different projection angles and in different positions with respect to the system axis 8. The output signals which are produced from the individual detector elements 6a to 6x in this case are read, conditioned and digitized by a data acquisition system 10, which is essentially arranged on the gantry 7. The digitized signals, the so-called raw data RD, are or is supplied by means of a transmission path 11, which contains an electrical cable and/or an optical waveguide as well as a slipring system or a wire-free transmission path (in a manner which is not illustrated), to a signal processing appliance or to an image computer 12, which calculates an image of the patient 3, and this image can in turn be reproduced on a monitor 13. The monitor 13 is connected to the image computer 12 by means of an electrical cable 14. The steps of air calibration, channel correction for non-linearities, spacing correction, water calibration and image reconstruction, inter alia, are carried out in the image computer 12.

The data acquisition system 10 contains a radiation

monitor 15 which is arranged on the emitter side, measures the radiation power of the X-ray beam source 1, and whose output signal is used in the image computer 12 for normalization of the raw

data. The entire signal channel which is associated with the radiation monitor 15 is also referred to as the monitor channel.

The computer tomography unit illustrated in Figure 1 can be used both for sequence scanning and for spiral scanning.

In the case of sequence scanning, the patient 3 is scanned in layers. In this case, the X-ray beam source 1 and the radiation detector 4 are rotated around the patient 3 with respect to the system axis 8, and the measurement system, which comprises the X-ray beam source 1 and the radiation detector 4, in each case records an attenuation profile (linear integral) in each of a large number of projections, in order to scan a two-dimensional layer of the patient 3. The image computer 12 uses the measured values (raw data RD) obtained in this way to reconstruct a section image which represents the scanned layer. The patient 3 is in each case moved along the system axis 8 between the scanning of successive layers. This procedure is repeated until all of the layers of interest have been recorded.

During spiral scanning, the measurement system, which comprises the X-ray beam source 1 and the radiation detector 4, is rotated with respect to the system axis 8, and the table 9 is moved continuously in the direction of the arrow b, that is to say the measurement system which comprises the X-ray beam source 1 and the radiation detector 4 is moved relative to the patient 3 continuously on a spiral path c until the area of the patient 3 of interest has been recorded completely. A volume data record is generated in this case. The image computer 12 uses this to calculate planar data, using an interpolation process, from which

section images are reconstructed, in the same way as for sequence scanning.

An evaluation device 18 is provided in a control computer (host) or computer 16

which is fitted away from the gantry 7, that is to say it is stationary, and is formed as a functional group by driving the computer 16 by means of software provided in the computer 16. The evaluation device 18 is used for automated assessment of the quality of the DMS (Data Measuring System), which comprises the data acquisition system 10, the transmission path 11 and the radiation detector 4. Evaluation algorithms are run in the computer 16 for this purpose.

Once the evaluation device 18 has been triggered, it carries out the following steps automatically, without any further human inputs being required:

a) initiation of one or more measurements for production of raw data, which is also supplied to the computer 16 via the data transmission path 11;
b) using the direct raw data or raw data which has been normalized on the basis of the monitor channel, calculation of at least one value of at least one parameter which allows a quality statement;
c) driving of a display device 20 in order to display an evaluation result, in which the calculated value is included.

Depending on the respective specific parameter calculation, after step b) the evaluation device 18 carries out a comparison of the calculated value with a tolerance limit which can be predetermined or is read from a memory 21. A comparative illustration can then be displayed in the evaluation result on the display device 20.

The evaluation result is displayed graphically.

In order to allow comparison with earlier quality tests, in particular for assessment of the long-term

stability of the data acquisition system 10 and of the radiation detector 4, evaluation results can be stored in a memory

device 22, and can be reloaded from there, in particular for a parameter which results from a comparative calculation.

The exemplary embodiments which are described in the following text describe in detail the method of operation, as demonstrated with reference to Figure 1, of the evaluation device 18 for specific test measurements.

Figure 2 shows, schematically and in detail, the data acquisition system 10 as illustrated in Figure 1, whose function and quality are tested by the evaluation device 18.

Each detector element 6a to 6x is followed by a respective integrator 30a to 30x, which is a capacitor. Figure 2 illustrates only the integrators 30a and 30x. The integrators 30a to 30x may also, in contrast to Figure 2, be formed by amplifier stages or, to the extent that they are a component of the detector elements 6a to 6x, may themselves have an integrating effect as the detector elements 6a to 6x.

The integrators 30a to 30x integrate the charges (which are produced in the detector elements 6a to 6x on absorption of X-ray radiation) for each sampling step over a specific time interval, and these charges are read and amplified row-by-row sequentially by means of a demultiplexer 31 and by means of an electronics element 32; that is to say the signals which have been read are applied sequentially at the output of the electronics element 32 firstly to the detector element 6a, then to the detector elements 6b to 6f, and then to the detector elements 6g to 6l, and so on. Alternatively, the detector elements 6a to

6x may also be read in columns.

The signals from the detector elements 6a to 6x, after having been read and amplified by means of the electronics element 32, are then digitized sequentially by means of an analog/digital converter 33, and are optionally supplied to a so-called arithmetic logic unit (ALU) 34. The digitized signals are supplied to the image computer 12 via the transmission path.

In order to test individual components of the data acquisition system 10, the evaluation device 18 carries out a number of measurements successively, on the basis of which it is possible to assess whether and if appropriate where in the signal path a quality defect has occurred in the data acquisition system 10, so that any fault or defect which may be present can be associated, at least with a high probability, with a specific component.

The evaluation device 18 offers various algorithms for testing of the radiation detector 4 and of its detector elements 6a-6x, with the particularly advantageous evaluations being described in the following text:

A) check of the offset values (signal offset) of the detector elements 6a-6x:

The offset values are dark values (without X-ray radiation), which are preset in order to allow correct A/D conversion. The offset values must be in a specific optimum range. This check may also be regarded as a check of the "detector channels".

After it has been triggered, the evaluation device 18 carries out the following steps automatically:

a) Initiation of the recording of a raw data record with the gantry 7 revolving or being stationary, but with the X-ray beam source 1 switched off. 1000 to 2000 individual values are typically recorded in this case for each detector element 6a-6x.

b) A mean value and a standard deviation are calculated from the individual values for each detector channel as parameters which allow a quality statement.

c) The means values and standard deviations are displayed as numerical values or as a bar chart (for example with a channel number on one of the diagram axes) on the display device 20.

B) Check of the signal linearity (relationship between the received signal and the incident X-ray radiation power)

Figure 3 shows a corresponding flowchart.

After the start, the evaluation device 18 first of all, in a first step 41, sets the X-ray beam source 1 with a first tube current I_1. In a second step 43, the gantry 7 is revolved, and data from the detector elements 6a-6x is measured. During the process, a first raw data record RD1 is formed successively or subsequently in a third step 45. In a fourth step 47, a second tube current I_2 is set, which is not the same as the first, and another gantry revolution is carried out in a fifth step 49, with a second raw data record RD2 being formed in a sixth step 51. The tube voltage and thus the X-ray spectrum remain the same for both raw data records RD1, RD2. The raw data records RD1, RD2 are used to form ratios on a channel basis in a seventh step 53, and are related to the ratio of the tube currents I_1, I_2. A test result which includes both ratios is either displayed immediately for each channel, or first of all only for each row, with the option of obtaining a recording of the test results from the individual channels only if the test result is unsatisfactory (eighth step 55).

C) Check of the spectral linearity (relationship between the received signal and the spectral composition of the incident X-ray radiation)

Figure 4 illustrates a corresponding flowchart.

After the start, the evaluation device 18 first of all sets the X-ray beam source 1 to a first tube voltage U_1 in a first step 61. In a

second step 63, one revolution of the gantry 7 is carried out, and data is measured from the detector elements 6a-6x. During this process, a first raw data record RD1 is formed successively or subsequently in a third step 65. A second tube voltage U_2, which is not the same as the first, is set in a fourth step 67, another gantry revolution is carried out in a fifth step 69, and a second raw data record RD2 is formed in a sixth step 71. The tube power remains the same for both raw data records RD1, RD2, that is to say the tube current has been matched appropriately. The ratios of the two raw data records RD1, RD2 are formed on a channel basis in a seventh step 73, and are related to the ratio of the tube voltages U_1, U_2. A test result which includes both ratios is either displayed immediately for each channel, or first of all only for each row, with the option of obtaining a recording of the test results of the individual channels only if the test result is unsatisfactory (eighth step 75).

In order to test or check the data transmission path 11 from the radiation detector 4 to the image computer 12, the evaluation device 18, in this case in particular DMS test software in the monitoring computer 16 of the CT unit, drives the CT unit with or without X-ray radiation. This procedure is illustrated in Figure 5.

First of all, the scan parameters required for the test are set (arrow 81). The data acquisition system 10 of the DMS is configured - for example by means of specific test settings on microcontrollers - so as to produce predefined test data. A number of scans (measurements) are then carried out. The data produced by the data acquisition system 10 is transmitted via optical waveguides and a slipring to the receiver 80 for the image computer 12 (arrow 82). The signal may be subject to disturbances on the transmission path 11, for example by the production of the X-ray radiation

(interference S1) and by the ring motor of the gantry drive (interference S2). In order to make it

possible to distinguish between the different interference sources, separate tests are carried out:
i) scans with radiation and without radiation in order to identify faults which are caused by the production of the X-ray radiation,
ii) scans without radiation and with rotation in order to identify faults which are caused by the drive.

The image computer 12 then carries out consistency tests on the received data, for example by forming bit cross sums by means of CRC (Cyclic Redundancy Check), by analyzing the amount of received data, and/or by analyzing the values of the received data.

The test software in the host computer 16 checks the faults which occur during the measurements from the image computer 12 (arrow 83) and from slipring electronics (arrow 84) and produces these faults in the form of texts and graphics. The results are displayed on the display device 20 (arrow 85).